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ABSTRACT

This paper, written for those in higher education mathematics departments, reviews curriculum reform. Three major reasons for programmatic reform are outlined: (1) higher education faces a changing climate; (2) higher education faces a challenging clientele; and (3) mathematics educators face a changing content. The case is made for programmatic review and reform based on five fundamental operating principles that include active learning, accessibility, applicability, assessment, and accountability. (MM)

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PROGRAMMATIC REFORM: THE CARE AND FEEDING OF A MATHEMATICS MAJOR

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Mathematics departments across the country (and world-wide) are currently at various stages of curriculum reform. Some are just now thinking of starting implementation efforts (usually at the calculus level) and are looking at various existing models, while others have a decade or more of experience at moving beyond the traditional lecture format and content-driven curriculum. In the latter departments reform has generally spread far beyond calculus, reaching from upper-level courses to service and developmental courses. A major question now looms before such departments: what comes next? The answer: programmatic reform.

To see why, let's examine the current state a little more carefully. Most reform efforts have been centered around individual courses, using one or more of the following approaches: active learning, applications-based problem solving, cooperative learning, discovery learning. The incorporation of technology generally plays a central role, which necessitates students (and faculty) learning new software for almost each course. Courses are designed to be more student-centered, allowing the student to control her learning process, although that seems to be more a dream than a reality. Many aspects of these reforms seem unique to a given environment and instructor, with variables including the availability of technology, the types of students in a particular course, and the departmental atmosphere. It is rare that a department can just adopt a set of available curriculum materials and head to the classroom, with no or little thought as to how to adapt them to that particular situation.

Hence the need for programmatic reform, which asks two major questions:

* How do we blend these individual changes into a coherent package?

* How do we meet the needs and desires of the students and stay within ever-tightening budgets?

In answering these questions, especially the latter, we are reminded of the standard warning from systems analysis that what a client *says he wants* is usually different from what he *really wants*, which is in turn different from what he *needs*, which is not the same as what his *resources will allow*.

Making the process of programmatic reform more difficult is the changing environment of higher education in general and the teaching of mathematics in particular. Let's analyze briefly the current situation.

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1. Higher education faces a changing **climate**.

*Parents and students, and consequently administrators, emphasize value for the dollar. Many private colleges are already finding students making college choices on the basis of which institution is cheaper, with a $100 difference in tuition swaying choices. We seem to be living in a Wal-Mart society, with little thought to the consequences of our decisions: What are we giving up for lower costs? Will lower prices today mean less competition (and higher costs) tomorrow? Are some aspects of an education necessary no matter how expensive?

*The technological explosion makes it almost impossible to keep on top of the latest developments. Few institutions can afford to continually purchase state-of-the art equipment, and few instructors can manage to keep tabs on all the latest software. Often entering freshmen have used hardware or software not yet available at their college or university.

*Our society is saturated with information. Many educators are convinced that colleges and universities, which have for decades (if not centuries) seen their fundamental role as teaching students how to obtain information, will have to adapt to a new paradigm: teaching students how to evaluate and judge the quality of information, and then how to draw quality inferences from that information.

2. Higher education faces a challenging **clientele**.

*Students and parents see education as a conduit to a job rather than as an important goal in its own right. Choices of major are often made on the basis of how many employment want ads specify a job title connected with that major. Even specific courses are viewed through the filter of their importance on a resume.

*Students have been exposed to a great deal of technology, but their knowledge is often superficial. They may be aware of many aspects of the latest innovations, but often their understanding goes at most to the level of a casual user, so that even minor changes may result in a need for retraining.

*Students are still conditioned under the old paradigm to be information-seekers. Obtaining information is considered an end in itself. Changing ingrained habits takes both patience and a conscious effort to motivate students to make such changes.

3. Mathematics educators face a changing **content**.

*Current curricular reforms emphasize innovation. As long as the pot is being constantly stirred, it's hard to see what's cooking and how well done it is.

*Current curricular reforms rely on technology. Given the rapid changes in technology, this is like learning to drive using a different car each day. While the underlying principles may remain the same, the differences may distract from the fundamental goal.

*Current curricular reforms are still information-centered, focused on the old paradigm. Many questions remain to be answered regarding how much and what type of information is needed to form an adequate foundation while still working on the development of understanding of mathematical processes (such as experiment-conjecture-proof) and lifetime learning and professional skills (including communication and collaboration).

So with such shifting sands below our feet, how can we begin to implement programmatic reform? At Franklin College, we have already taken what we feel to be the first steps in that direction. As background, let me mention that Franklin is a small private baccalaureate institution with 900 students, 45-50% of whom are first-generation college students, many of them from small towns in Indiana. Incoming freshmen average about 1000 on the old SAT (before recentering). The Department of Mathematical Sciences has five full-time and one continuing 3/4-time faculty positions and offers majors in pure mathematics, mathematics education, applied mathematics, computer science, and information systems. We have been at reform over seven years, with the first formal step being the introduction of weekly scheduled labs into the first year calculus courses in 1989. We have access to computerized classrooms on a basis ranging from once a week for our liberal arts mathematics class to every day for such heavy users as numerical analysis and multivariable calculus. (This access illustrates one of the advantages of curricular reform in small institutions, along with class size and the smaller number of instructors involved in teaching any given course; the fact that our teaching loads average 24 hours per year with up to six preps and no graders available provides a strong downside to attempts to keep each course at the cutting edge.)

The most dramatic and rewarding stride we have made in programmatic reform is to develop a set of four-year goals and objectives for students completing a major in mathematics. From this framework goals and objectives were formed for each course and sequence of courses available to majors, and then for service and developmental courses. Globally these goals provide a basis for decisions on curriculum requirements, departmental assessment of student learning, and departmental initiatives and priorities; locally they allow instructors to make informed decisions regarding instructional methods and content within individual courses. The goals focus on three general areas:

*Mathematical concepts, including definitions, theorems, computations, and applications;

*Mathematical processes, such as the experimentation-conjecture-proof cycle or the interactive dynamic in modeling between real-world and theoretical results;

*Lifetime learning and professional skills, e. g., communication, collaboration, and use of technology.

From these goals we produced developmental strands, so that faculty teaching the writing of proofs in a real analysis course would know that students had been exposed to proof concepts in calculus and that the experimentation-conjecture-proof cycle had been a major emphasis in the required linear algebra class. In this way we can assure ourselves that primary emphases are addressed and reinforced in a conscious manner. It also makes it easy for instructors to contact

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those who taught courses earlier in the developmental strand to know at what level students should enter their courses.

Our most recent step has been programmatic review, examining each major course of study in mathematics to see if each goal and objective is adequately addressed in the courses required for the major. We also looked at each group of non-majors taking courses in the department to see that their mathematical needs were addressed in a coherent fashion.

Our efforts thus far have been guided by a set of fundamental operating principles. They can be characterized as:

***Active learning**

If education is to have any real lasting benefit in preparing for a lifetime of learning, students have to be involved as more than passive targets in the learning process. Active learning incorporates a broad range of techniques, including discovery learning and cooperative learning, as well as addressing a wide variety of learning styles.

***Accessibility**

This incorporates two fundamental ideas: achieving student buy-in to course objectives by effective communication of the rationale behind their development, and aiming courses at a reasonable level for where students are, not where we wish they were.

***Applicability**

This principle likewise has two facets: demonstrating connections to other disciplines, and highlighting relationships to potential jobs and fields of graduate study.

***Assessment**

We have to be innovative to devise assessment instruments which relate to our goals and objectives, many of which cannot be adequately evaluated by traditional tests, quizzes, and written assignments. For example, in our senior seminar course at Franklin, which serves as a capstone experience, we have supplemented the long-standing hour-long oral comprehensive exam and nationally-normed multiple-choice exam with a "joint written comprehensive exam", in which teams of four to five students spend a week developing answers to about five questions which require modeling, writing proofs, and use of library and information resources. This exam is written and graded by a professor at another college as an external review mechanism. Similarly, new teaching methodologies require new assessment tools. We need to be experimenting with a wide variety of assessment instruments so that we obtain needed feedback and also so that we can steer more global (e. g., university-wide) assessment efforts in directions which will most beneficial.

*Accountability

> While many see accountability as a dangerous concept to be feared and avoided so that colleges and universities can try to continue to be the judges of how well they are succeeding, the truth is that the climatic changes in education as noted above will produce more and more demands for accountability from boards of trustees, from students and parents and from the public in general. We should be out in front asking to be held accountable so that we have a voice in setting goals and in deciding how accountability should be determined.

In summary, programmatic review means asking what we're trying to do, how do we do it, and how do we know if we've done it. It means looking at the entire undergraduate and/or graduate experience as an integrated and sequential whole, not just isolated parts at specific points in time. And it means connecting that experience to the world outside of higher education, cognizant of what happens to students before they matriculate and what happens to them after they graduate. Once we have that framework in place, then curricular reform can achieve its full potential in transforming mathematics education.